Experimental report

30/06/2016

Proposal: 3-14-350 **Council:** 10/2014

Title: Measurements of small heating of UCNs and total losses of UCNs in traps coated with Fomblin oils of different polymeric molecular weight

Research area: Nuclear and Particle Physics

This proposal is a new proposal

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Samples: Fomblin oils with different molecular weight

Instrument	Requested days	Allocated days	From	To
PF2 UCN	50	50	17/06/2015	06/08/2015

Abstract:

Fomblins are oils of a special kind, in which Hydrogen atoms are substituted with Fluor atoms. One application of such oils is their use as coatings for material bottles in experiments with storage of ultracold neutrons (UCNs). Fomblin oils with different polymeric molecular weights demonstrate significantly different physical properties. This difference is expected to result to different behavior and size of UCN losses. We are going to measure the probability of total losses of UCNs and also the probability of small heating of UCNs for Fomblins with different oil molecules as a function of the molecular weight, the temperature, the energy and the time evolution. The results are important for analysis of existing neutron lifetime experiments, for properly designing future neutron lifetime experiments with largely improved accuracy and for analysis of contributing mechanisms of small heating of UCNs.

Fomblins are oils of a special kind, with Hydrogen atoms substituted with Fluor atoms. One application of such oils is their use as coatings for material bottles in experiments with storage of ultracold neutrons (UCNs). The interaction of UCNs with the surface of such oils is interesting both in view of investigating so-called "small heating" of UCNs, as well as for exploring feasibility of increasing the accuracy of neutron lifetime experiments. Correct interpretation and analysis of neutron lifetime measurements and other experiments using UCN storage is conditioned by clear understanding and control of mechanisms of UCN losses from traps. Unfortunately, the problem is quite complex: the probability of UCN losses on Fomblin surfaces is reported to evolve in time; losses are caused by several mechanisms including nuclear absorption, inelastic scattering to the thermal energy range, small heating of UCNs, with poorly defined partial contributions of these mechanisms; diluted gases further contribute to complicating the situation. In spite of a significant number of experiments carried out in this field and a significant number of groups involved in this research, a comprehensive phenomenological study of small heating of UCNs on the Fomblin surface has not yet been done, and also results of existing measurements scattered significantly more than the estimated uncertainties.

We assumed that the critical parameter, which defines the probability of small heating and the probability of total UCN losses on the surface of Fomblin oils, is the atomic weight of its long polymeric molecules. In order to verify this hypothesis, we measured the probability of small heating and total UCN losses on the surface of Fomblin oils as a function of several parameters including the mean molecular weight (2800, 3300, 6500 at. un.) and the temperature (100-300 K). To standardize the initial experimental conditions, we used oils as produced, without any preliminary treatment (heating, degassing etc). In order to eliminate any uncertainties concerning neutron spectra, we used the BGS spectrometer, which provides the highest presently available accuracy and reliability of absolute spectral measurements (quasi-mono-energetic UCNs in the initial spectrum and model-free measurements of resulting spectra).

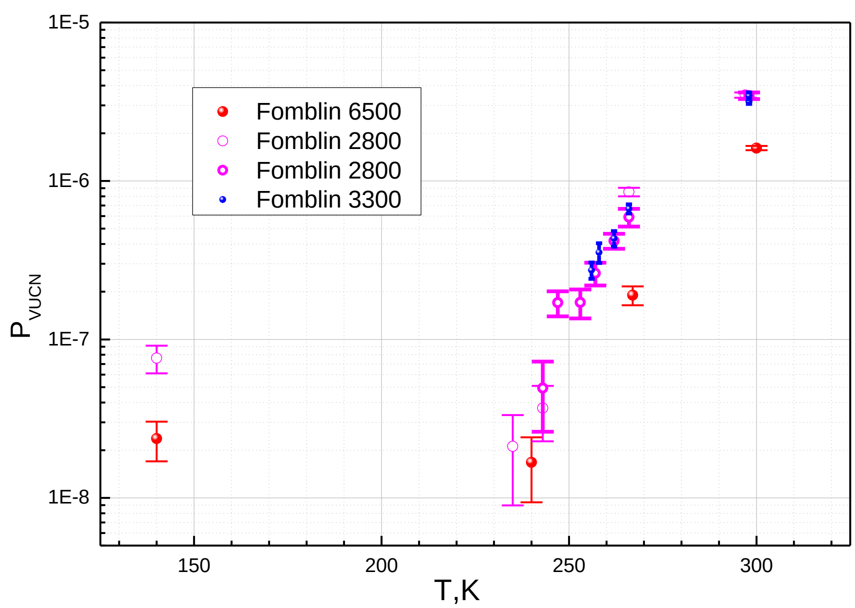

Fig. 1. The probability of small heating of UCNs on Fomblin oil surfaces as a function of temperature. The initial UCN energy is a narrow mono-line centered at about 30 cm; the energy range of efficient detection of neutrons after their quasi-elastic reflection is 35-82 neV. Points of different color correspond to measurements with Fomblin oils of different molecular weight, as specified in the figure.

The experiment showed that the probabilities are systematically reproduced as long as one fixes values of molecular weight and temperature; they do not evolve in time and systematically depend on values of the Fomblin molecular weight and temperature.

At a certain temperature, the probability of small heating is significantly larger for oils with small molecular weight than that for oils with large molecular weight. The relative difference increases with decreasing the temperature. For all samples, the absolute probability of small heating decreases rapidly with decreasing the temperature; at temperatures below 240 K, it becomes lower than 10^{-7} per bounce.

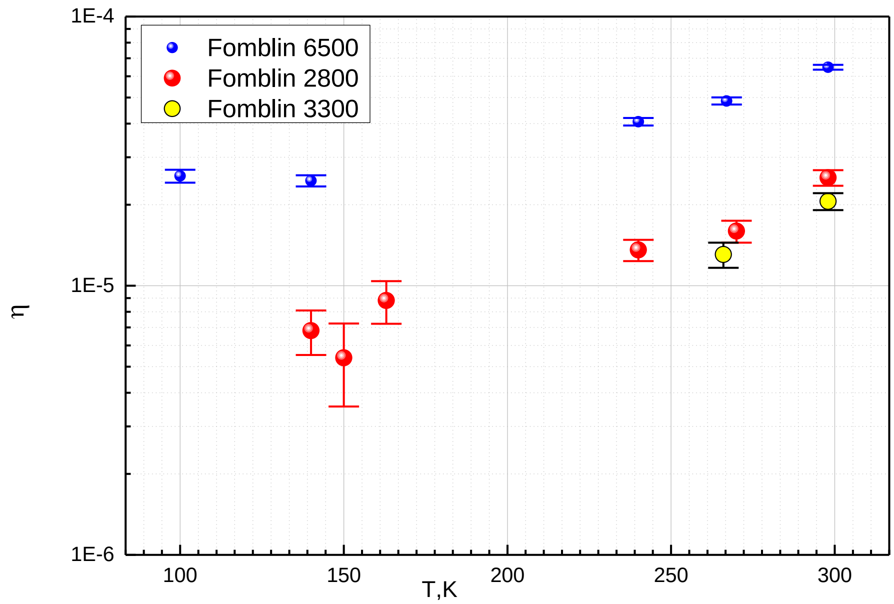

Fig. 2. The loss coefficient as a function of temperature for Fomblin oils of different molecular weight.

The minimum coefficient of total losses was measured for the oil with the mean molecular weight equal 3300. Such a type of oil is a favorite candidate, among the investigated options, for coating traps in precision neutron lifetime experiments.

Visual observation of cooled down oil coatings revealed spontaneous breaking of their continuity at temperatures in the range of 150-100 K; therefore such low temperatures should be avoided in precision neutron lifetime experiments.

The measured results are useful for investigations of mechanisms and details of the interaction of UCNs with surface, and also for designing a new generation of neutron lifetime experiments with significantly higher accuracy and reliability. In particular, the present experimental data will be later compared to predictions of particular models of small UCN heating. Concerning precision neutron lifetime experiments, we have identified a full set of parameters, for which no major false effect is present, measuring conditions and parameters are close to the ideal case, and realization of such a precision experiment is feasible.